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THE
ORDNANCE SURVEY
OF
THE KINGDOM

BY

CAPTAIN H. S. PALMER

THE

ORDNANCE SURVEY

OF

THE KINGDOM;

ITS OBJECTS, MODE OF EXECUTION, HISTORY, AND PRESENT CONDITION.

BY

CAPTAIN H. S. PALMER, R.E.

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THE

ORDNANCE SURVEY OF THE KINGDOM.

THERE is perhaps no great national work in this country which has hitherto been so little appreciated or understood as the Ordnance Survey. Certainly geographers and men of science, both at home and abroad, have learnt to estimate it at its true worth; but, except in Ireland and Scotland, where it has made more progress than in England, and where its uses and advantages are somewhat better known, the general public are by no means fully alive as yet to the great national value of accurate large-scale national maps. It has been the fashion to abuse the Survey well, as a slow and apparently endless "job," contrived and carried on chiefly for the benefit of country gentlemen and landed proprietors, and for the edification of our military Engineers. The proposal for the annual vote gives an opportunity each year for a few choice spirits in the House of Commons to raise an illogical lament over its continuance. Now and then some grumbler writes to 'The Times,' displaying astounding ignorance of the whole subject of the survey, and fostering the popular misconception: while, on the other hand, the Director-General's annual reports to Parliament, and the volumes, containing investigations of the highest order in geodetical science, which are from time to time issued by the department, share the usual fate of Blue-books and official publications, and excite but little attention outside official spheres.

The Survey, nevertheless, is gradually but surely making way in public esteem. So sensible are people at last becoming of its importance and usefulness, that several urgent appeals have lately been made for Government to grant the necessary funds for its speedy completion. Mr. Wren Hoskyns's motion last year in the House of Commons, Lord Derby's proposal for a new Domesday Book, and Mr. Galton's speech before the British Association at Brighton, all sound the same note—the hastening and utilisation of the maps of the Ordnance Survey. Under the able administration of Sir Henry James, assisted by an accomplished head-quarter staff, the department has risen of late years to a state of the highest efficiency, and is admitted, by all who have the means of judging fairly in the matter, to rank among the foremost, if not as the first, of our Government establishments. Foreigners readily acknowledge its preeminence. The committee of officers, appointed by the French ministers to examine the maps, plans and publications of the topographical departments of all nations represented at the Paris Exhibition of 1867, reported of the Ordnance Survey that it is "a work without precedent, and should be taken as a model by all civilised nations." We believe the subject to be one which only needs ventilating to ensure its due popularity and appreciation, and we accordingly set ourselves to the task of extracting from the Blue-books and reports upon the Survey a short account of its history and present condition, its objects, mode of execution and future prospects.

The trigonometrical survey of the United Kingdom may be said to have been begun eighty-nine years ago. Astronomers of that day were desirous that the difference of longitude between the Greenwich and Paris observatories should be ascertained by trigonometrical measurement; and, under the auspices of the King and of the Royal Society, General Roy, R.E., in April, 1784, began our part of the task by the measurement of a base-line on Hounslow Heath, which was to serve as the starting-point of a series of triangles to be extended to Dover and across the Channel. This work was carried out, a connexion with the French triangulation being established in 1786. Soon after this, the Government decided on having a general survey made of the entire kingdom, on the scale of one inch to a mile, for military purposes; and General Roy's triangulation in the south-eastern counties became the basis of the Great Triangulation, which was gradually extended over the whole of the British Isles, and finished twenty years ago. Under the successive superintendence of Colonel Williams, R.A., General Mudge, R.A., and Colonel Colby, R.E., assisted by Engineer officers and private surveyors, the one-inch survey, not without considerable interruption consequent upon the wars then going on, was carried northward through England and Wales, and by 1824 had reached the southern borders of Yorkshire and Lancashire.

At this time it became necessary that a survey of Ireland should be made, on a large scale, as a basis for a general land-valuation. On Colonel Colby's recommendation, the scale of six inches to a mile was agreed to: the work in England was suspended, and the force transferred to Ireland, non-commissioned officers and men of the Engineers being now for the first time associated with the officers in the duties of the survey, on the same system as at present. So valuable did the six-inch map of Ireland prove, for many purposes over and above that for which it had been expressly designed, that in 1840, when the Irish survey was completed and that of England resumed, the Government gave their consent to the adoption of the same scale for the unsurveyed parts of Great Britain. By 1851, Yorkshire, Lancashire, the Isle of Lewis, and several counties in the south of Scotland were finished on the six-inch scale. Then began that long controversy which has been well termed the "battle of the scales," and which for eleven or twelve years seriously retarded the progress of the survey, and led to a large waste of public money. Between 1851 and 1862, no fewer than three Select Committees, and one Royal Commission, deliberated on the scale for the survey, and fourteen Blue-books were presented to Parliament. In 1851 the six-inch scale was stopped, and the one-inch reverted to; in 1852 the six-inch was ordered again. In 1853-4 the Director of the survey was for fifteen months without orders for any scale at all. In 1854 the scale of $\frac{1}{2500}$ was partially adopted; in 1856 Parliament sanctioned the prosecution of the work on this scale; in the following year they refused the money for carrying it out. The department was well-nigh paralyzed by all this indecision and change, and by the constant fluctuations in the amount of the annual grant, which led more than once to the sudden dismissal, with pensions, of large numbers of civilian workmen, soon to be followed by their sudden re-engagement. On two occasions, large tracts of country had to be surveyed a second time, owing to changes in the orders as to scale. Altogether, in the ten years prior to 1862, a sum of at least 30,000*l.* was absolutely wasted in consequence of the vacillation of Parliament.

The main point of the controversy was whether the six-inch or some larger scale was best fitted for the national map. A host of persons eminent in science were consulted on the subject, and great diversity of opinion was found to exist, the weight of evidence however inclining, by a majority of four to one, to a scale of from 20 to $26\frac{2}{3}$ inches to a mile. In 1853, a Statistical Conference held at Brussels, and attended by twenty-six delegates from the chief States of Europe, considered the question of national maps or *cadastres*, and pronounced unanimously in favour of a scale of $\frac{1}{2500}$th of nature, equivalent to 25·344 inches to a mile, and therefore commonly styled with us the 25-inch scale; recommending, however, at the same time, that the *cadastre*, or *plan parcellaire*, on this scale should be accompanied by a more general map, a *tableau d'assemblage*, on the scale of $\frac{1}{10000}$, equivalent to 6·336 inches to a mile, and thus very nearly corresponding to our own six-inch scale.

The exact derivation and meaning of the French term *cadastre* are not free from dispute. Some authorities refer it to the verb *cadrer*, to "square" or "correspond with," all objects on a large-scale plan or *cadastre* being shown in their true positions and proportions, whereas in a mere topographical map similar accuracy is impossible, and certain features must needs be exaggerated for the sake of distinctness. The "Dictionnaire des Dictionnaires," on the other hand, derives *cadastre* (formerly *capdastre*) from the mediæval-Latin word *capitastrum*, (from *caput*, "head," because formerly *people* were taxed, and afterwards *property*), and defines it as "a public register, containing the quantity and value of landed property, names of owners, &c., and which serves for the assessment of the tax on property in proportion to its revenue." Brachet gives much the same description, but speaks of *caput* as bearing, in classical Latin, the sense of "amount of a contribution." But in the "Recueil des Lois et Instructions sur les contributions directes," the *cadastre* is defined as "a *plan* from which the area of land may be computed, and from which its revenue may be valued." This, there can be no doubt, is the sense in which the word is used on the Continent, while in England it is taken as denoting generally a survey on a large scale.

Let us now briefly examine the arguments in favour of the cadastral scale of $\frac{1}{2500}$, recommended by the Brussels Conference, whereby a mile on the ground is represented on the plan by the somewhat awkward number of 25·344 inches—why is this to be preferred to a scale of a more exact number of inches or feet to a mile. It is evident, in the first place, that, for purposes of international comparison and uniformity, the Government plans of all countries should be on simple *natural* scales, that is to say, on scales according to which the dimensions of objects as represented on the plans bear definite and easily remembered numerical proportions to their actual linear measures, and which are independent of any exact relations between conventional units of length, such as inches or feet, chains or miles. The scale, for example, of three chains to an inch, on which most of our Tithe-maps were drawn, may be very convenient in some respects for the English surveyor or engineer, but it is next to useless for general world-wide purposes, or for comparison with other scales, whether of this or foreign countries. On the other hand, plans on such scales as $\frac{1}{1000}$, $\frac{1}{2000}$, and so on, admit of easy comparison with one another, no matter what may be the national measures of the country or countries in which they were drawn; the proportions are at once understood by every one. Further, it was the opinion, as we have already mentioned, of nearly all the eminent men who, for reasons which will be presently touched upon, favoured a large national plan or *cadastre* for this country, that it should be drawn to a scale of certainly not less than 20 inches to a mile, *i.e.* four chains to an inch, or $\frac{1}{3168}$; some of them even advocated a scale of $26\frac{2}{3}$ inches to a mile, otherwise three chains to an inch, or $\frac{1}{2376}$. So far, therefore, as magnitude is concerned, the $\frac{1}{2500}$ scale is obviously suited to cadastral purposes. It is moreover a direct proportional of the decimal scale, and is a simple, easily remembered fraction. It also corresponds with the scales adopted for the national maps and plans of the chief countries of Europe. Austria, Belgium, France, Holland, Italy, Norway, Prussia, Sweden, and other States, have all conformed to the $\frac{1}{2500}$ scale, or to some definite part or multiple of it; and the rest of Europe, it can hardly be doubted, will sooner or later follow their example. Lastly, it possesses the incidental advantage that a square acre is to all practical intents represented on the plans by a square inch, the acre, in fact, corresponding to the square of 1·0018 inch.

After a long and minute investigation, the Treasury in 1855 sanctioned the adoption of the $\frac{1}{2500}$ scale for the cultivated districts of the four northern English counties, and of the unsurveyed parts of Scotland; and of the six-inch scale for the uncultivated districts; and the one-inch military map was to be carried on contemporaneously, and finished for the whole kingdom. Lord Duncan's Committee, in 1856, endorsed the Treasury decision, adding a proposal that the cultivated districts should be published on the six-inch, as well as the 25-inch scale; and the Royal Commission of 1858, presided over by Lord Wrottesley, made recommendations to nearly the same effect. In 1862, a Committee, of which Lord Bury was chairman, advised that the survey on the above scales should be extended to those parts of the United Kingdom which had, up to that time, been surveyed for the one-inch scale only. In March, 1863, the Treasury confirmed their recommendations. Here the controversy ended, and the survey has since then been carried on steadily, and as quickly as the sums annually granted would permit.

The final instructions, then, for the publication of the surveys of the United Kingdom may be summed up as follows; of the progress made we shall speak hereafter:—

1. A topographical map of the whole of Great Britain and Ireland, on the scale of one inch to a mile, or $\frac{1}{63360}$.

2. County plans of the whole of Great Britain and Ireland, on the scale of six inches to a mile, or $\frac{1}{10560}$.

3. Parish plans, on the scale of $\frac{1}{2500}$, or 25·344 inches to a mile, of the cultivated districts in England and Scotland, excepting Yorkshire, Lancashire, the Isle of Lewis, and six counties in the south of Scotland, previously finished on the six-inch scale; (these, however, we may suppose, will be revised to the 25-inch scale, when the rest of the country is finished).*

4. Plans, on the scale of $\frac{1}{500}$, or 126·72 inches to a mile, of all towns with more than 4000 inhabitants,† excepting London and its environs, for which the scale of 60 inches to a mile has been selected.

The relative arrangement and proportions of the plans on the three last-mentioned scales will perhaps be made clear to the reader by the following description. A six-inch plan is a rectangle 36 inches by 24, thus including 24 square miles of country, or 15,360 acres. If this be divided into 16 rectangles, 9 inches by 6, each of these rectangles marks the portion of country included in a plan on the $\frac{1}{2500}$ scale: such portion will evidently be $1\frac{1}{2}$ miles long, by 1 mile wide, equivalent to 960 acres; and the plan, when drawn to scale, will measure 38·016 inches by 25·344 inches. If one of the small rectangles be further divided into twenty-five smaller ones, measuring 1·8 inch by 1·2 inch—corresponding to $\frac{3}{10}$ths of a mile by $\frac{2}{10}$ths of a mile, or superficially 38·4 acres—each of these will represent the portion of ground included in a plan on the $\frac{1}{500}$ scale, which plan, when drawn, will measure the same as a $\frac{1}{2500}$ plan. It seems a pity that, in place of the scale of six inches to a mile, or $\frac{1}{10560}$, the fractional scale of $\frac{1}{10000}$, recommended by the Brussels Conference, could not have been adopted for our county maps. It would have been a definite proportional of the scales of the parish and town plans, and the sheets in all three cases would have been of precisely the same dimensions. But we were by this time too far pledged to the six-inch scale, which had been adopted for the engraved sheets of all Ireland, and part of England and Scotland. Similar reasons, doubtless, prevented the rejection of the one-inch ($\frac{1}{63360}$)

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* The county of Dublin has also been specially published on the 25-inch scale, at the request of the Chief Valuator for Ireland.

† Prior to this order, a number of towns had been published on the scales of 5 feet or 10 feet to a mile. Probably, however, in the course of time the whole of the towns (London excepted) will be published on the one uniform scale of $\frac{1}{500}$.

in favour of a more simple fractional scale, such as $\frac{1}{50000}$, or $\frac{1}{75000}$, for our topographical map.

The one-inch sheets are arranged without reference to the sheets on other scales. Those of Scotland are drawn to a central meridian for that country, on Flamsteed's modified projection. Ireland also has its own meridian; but the special projection employed could hardly be made clear without a tedious digression. It is to be regretted that the early one-inch sheets of England and Wales were not constructed uniformly to one proper geometrical projection for the whole country. As it is, the south-eastern counties were drawn with reference to the meridian of Greenwich, those of Dorset to the meridian of Black Down, those of Devon and Cornwall to the meridian of Butterton Bill, and so on. It is evident that the sheets thus constructed cannot be fitted accurately together, so as to form one complete map, on which all objects would appear in their true relative positions. The mistake, however, is being remedied. One central meridian, that of Delamere, in Cheshire, has been adopted for England and Wales. The sheets of the six northern counties have all been laid out with reference to it, on a similar projection to those of Ireland; and the new sheets in the south, as they are gradually prepared in connexion with the cadastral survey, are being adapted to the same uniform system. The one-inch map of England and Wales is being published, like that of Ireland, in quarter-sheets, each 12 inches by 18 inches, and containing 216 square miles. The Scotch one-inch half-sheets measure 18 inches by 24 inches, each one thus containing 432 square miles.

The six-inch sheets are constructed separately for *each* county, with reference to a central meridian for that county, except where two or three counties lie so well north and south of one another that the same meridian serves for more than one.

We have seen why the fractional scale of $\frac{1}{2500}$ was chosen in preference to the nearly equivalent scales of three chains or four chains to an inch. It will be well at this point to explain briefly the reasons in favour of any such large scale at all. The maxim that a country, in undertaking a national survey, practises a wise economy in making it once for all on a scale large enough to subserve every necessary public purpose, admits of easy proof, so far at least as this kingdom is concerned. It is a cardinal axiom with topographers that, though a parent survey can be reduced, it cannot with accuracy be much enlarged. A survey, for instance, once made for the 25-inch scale, is capable of easy reduction by scientific processes to the six-inch, one-inch, or any such smaller scales as may be desired, more and more of the unnecessary details being omitted as the scale is reduced. On the other hand, a survey made with the view of being published on the one-inch scale only, or even the six-inch, is inadequate for a map on the 25-inch scale; even if the measurements, so far as they go, be accurate enough, the whole must be re-plotted and tested, and many details must be added; much of the work, in fact, will need to be gone over again, at great additional expense. But in this country, the extra cost of making the survey in the first instance for the 25-inch scale bears only a small proportion to its cost as for the six-inch. Down to the completion of the manuscript plan, the additional expense does not exceed 13 or 14 per cent.; while the cost of publication is the same, acre for acre, on either scale. Unless, then, it can be shown that a six-inch map adequately fulfils all national purposes (for the one-inch is out of the question), the difference between its cost and that of a 25-inch map is so slight that preference should certainly be given to the latter, which furnishes all the materials for publication on the smaller scales as well.

The public purposes which a national map should subserve, apart from those which are purely geodetical or geographical, are too numerous and extensive for us to discuss here in detail. Amongst the chief of them are the following; the valuation of property for the equitable adjustment of taxation and assessment; the sale and transfer of land, and the registration of title; railway and other civil engineering works, such as the construction of roads and canals; large sanitary and drainage schemes; military engineering works; hydrographical, geological, and mineral surveys; the reclamation and improvement of waste lands, and of land from the sea; transactions affecting land as between landlord and tenant; statistical surveys; the setting out and adjustment of parochial and other public boundaries; and so forth. It has been amply proved by the best evidence on the subject that in this country a map, with levels, on a scale of something like 25 inches to a mile, is the smallest which can properly fulfil all these requirements. We will adduce but one instance out of many in support of this view. The six-inch survey of Ireland is held to be one of the most valuable acts of practical government that has ever been carried out in that country. The maps were regarded at the time of their production as unrivalled specimens of topographical art. They came into almost universal use in all dealings which related to the acreage of land. The Income-tax, as collected according to the valuation founded on the basis of the Ordnance maps, exceeded the amount previously collected by nearly £50,000 a year, the Chief Valuator nevertheless stating that the cost of the valuation would have been diminished by one-fourth, if not by one-third, had the plans been drawn on the 25-inch scale. But, when the Encumbered Estates Court, or, as it is now called, the Landed Estates Court, was established, the six-inch maps were found to be utterly insufficient for the purposes of land-sales under the jurisdiction of the Court. The estates accordingly had to be revised to the 25-inch scale. This revision is still in progress, and already about 2000 square miles, or more than one-seventeenth of the whole of Ireland, have thus been redrawn since 1859, at the expense of the suitors at the Court.

The history of the large sums which, even within the last thirty years, have been from time to time expended on incidental surveys, for various public purposes, also furnishes an instructive lesson on the economy and advisability of being provided with a systematic national *cadastre.* In 1842, when the Tithe Commutation Act passed, a demand arose for a great number of plans on a large scale. That demand was supplied by plans got up in a hasty and impromptu manner, on different scales, on no uniform principle, and without reference to any general system of triangulation. Of 12,000 tithe-plans thus prepared, and extending to three-fifths of the country, about one-sixth only are of a first-class description; many of the remainder are very imperfect and inaccurate, some of them indeed scarcely worthy of the name of plans, and useless for public purposes. Two millions of money, a sum which would have more than paid for a 25-inch national survey of England, were thus spent on plans which can never be juxtaposed so as to form a national *cadastre*, and which would not have been needed had a *cadastre* existed. But this is not all. When the operations of the Tithe Commission were afterwards extended to other objects, many of the maps were found to be inadequate to any but the special purpose for which they had been designed, and much of the work had to be done over again. In 1856, the Inclosure Commissioners spent £40,000 for fresh surveys and maps; these too, unfortunately, being made on no uniform system. On the occasion of the railway mania, in 1845, another immense demand arose for maps for railway surveys. Three-fourths of the tithe-plans proved useless for this purpose. A sum of about £250,000 was spent on surveys for the railways which were actually carried out, £200,000 of which might have been saved had there been a national *cadastre;* to say nothing of the cost of negotiations with landowners, much of which would have been avoided had there been Government maps on which owners of property could have relied. Besides this, hundreds of thousands, almost millions, were expended on surveys for lines which were got up in a hurry, and then abandoned from the want of proper maps with levels.

We might go on multiplying instances in which enormous sums of public money have thus been absolutely squandered. Enough has, however, been said to prove the importance and economy of having a good cadastral plan of the country, and the policy of making it, while we are about it, on the 25-inch scale. The maxim that what is worth doing at all is worth doing well is eminently true of our national survey. The triangulation, which forms no inconsiderable part of the whole cost and trouble of a survey, was finished, and brought to mathematical perfection, by 1858. It formed a framework on which a survey on any scale whatever might be carried out. Having completed this, it would have been in the highest degree impolitic to stop short at the six-inch scale, for the sake of saving 13 or 14 per cent., and with the almost certain prospect of having sooner or later to do much of the work over again. We may well rejoice that the Government were led to take a large and enlightened view of the question, and Sir Henry James is certainly entitled to the thanks of the country for the far-seeing ability and persistency with which, in the teeth of much opposition, he pressed and successfully maintained the true policy of executing our national survey thoroughly, once for all.

THE GREAT TRIANGULATION.

The principal triangulation of the British Isles was begun, as we have already mentioned, in 1784, and finished in 1852. By means of it, the positions of about 250 trigonometrical points in all parts of the country have been determined with the most refined precision. From the Shetlands to the Scilly Islands, and from Valentia to Lowestoft, the whole kingdom has been covered with a great network of imaginary lines, the lengths of which are so accurately known that the computed distance, for example, between Snowdon in Wales and Slieve Donard in Ireland, though upwards of 100 miles, cannot be more than a few inches in error.

Two principal base-lines and four bases of verification were measured in the course of the triangulation. The former, which are situated on Salisbury Plain, and on the border of Lough Foyle, were measured with General Colby's 10-feet compensation bars. This apparatus is a marvel of ingenious scientific contrivance, bars of iron and brass being combined in such a manner that the distance between two fine dots, on steel tongues connecting them at their extremities, remains constant at all temperatures. The bars are laid perfectly horizontal, and in a perfectly straight line, with the aid of levels and a directing telescope; and, to avoid disturbance of a bar when once in position, the next, instead of being brought into contact with it, is so placed as to leave an interval of 6 inches between their ends, this interval being measured with a double microscope, the two foci of which are kept at all times exactly 6 inches apart, by means of a compensating apparatus, constructed on the same principle as the bars themselves. The Lough Foyle base was thus measured in 1827-8, and is about 41,641 feet in length; the Salisbury Plain base, measured in 1849,* is about 36,578 feet long. Some idea of the excellence of

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* This was the second measurement. By the first, made with steel chains in 1794, it was about a foot shorter.

Colby's apparatus, and of the care with which it was used, may be gathered from the fact that, on a subsequent occasion, when 500 feet of the Lough Foyle base were remeasured, in the presence of Sir John Herschel and Mr. Babbage, the difference between the old and new measures was only one-third of the finest dot that could be made with the point of a needle.

Not less remarkable was the minute and ever watchful care bestowed on the measurement of the angles of the triangulation, a task in which thirty-four observers, twenty-nine of them being officers and non-commissioned officers of Engineers, have at different times taken part. Two magnificent 3-feet theodolites, made by Ramsden, one for the Royal Society, the other for the Master-General of the Ordnance, an 18-inch theodolite, also by Ramsden, and a 2-feet theodolite, by Troughton and Simms, were used in these observations. Years of anxious and patient scientific toil were devoted to the task. But it is manifest that no instruments, however beautifully made, and no observations, however numerous and careful, could result in a triangulation that should be of perfect geometrical accuracy—such, namely, that the sum of the angles of each plane triangle should be exactly 180°, and the sum of the angles round each station exactly 360°, and that the calculated value of the distance between any two of the trigonometrical points should be the same, by whatever series of angles it might be obtained.

The Ordnance Surveyors, nevertheless, were bent on attaining to this mathematical perfection. The method of least squares was employed for computing the small quantities by which the observed angles required to be corrected in order to make the whole triangulation geometrically exact. The labour and difficulty of this formidable undertaking were truly prodigious. Twenty calculators were at work upon it for between three and four years. The whole series of triangles was divided into twenty-one parts, and the necessary equations of condition were found, first for each separate figure, and finally for the whole group together. In one of these figures, the computers had to grapple with the appalling task of solving equations with seventy-seven unknown quantities. So great, however, had been the accuracy of the observers' work, that the average amount of correction to the observed angles was no more than $0''\cdot6$.

The whole of the work up to this stage was now put to a most rigid test. The bases on Lough Foyle and Salisbury Plain are about 360 miles apart. Taking the measured length of the former to start with, the length of the Salisbury Plain base was computed through the long intervening network of triangles, and compared with its measured length. The difference was found to be but 0·4178 foot, or little more than 5 inches. It is hardly possible to imagine a result more wonderful and satisfactory than this; Sir Henry James has well described it as a genuine triumph in geodesy. As the difference thus found could not be attributed to one base more than the other, it was so divided between them that each should exhibit an error proportional to the square root of its length; a mean base was thus obtained, and used in the final reduction of the triangulation.

The four bases of verification are situated on Hounslow Heath, at Misterton Carr, Belhelvie, and Rhuddlan Marsh. They were measured with Ramsden's steel chains, in 1791, 1801, 1817 and 1806, respectively, their lengths varying from about 4·64 to 5·19 miles, and the differences between the lengths as measured and as computed from the mean base being 2·076, 2·292, 2·880, and 19·152 inches. The Rhuddlan Marsh base is so unfavourably situated with respect to the neighbouring trigonometrical stations that little weight can be given to its computed value. The other three, however, exhibit discrepancies so extremely small—about the same, in fact, as those of the bases measured with compensation bars—as to justify the fullest confidence in steel chains of good make as base-measuring apparatus. The Hounslow Heath base had been previously measured, in 1784, by General Roy, with deal rods and glass tubes. The former, from their susceptibility to moisture, were considered a failure, and gave a result 24·24 inches greater than the measurement in 1791. The latter, however, gave a result only 2·72 inches less than that of 1791, or 4·79 inches less than the length afterwards computed from the mean base.

Many of the sides of the principal or primary triangulation are of great length, 66 of them exceeding 80 miles, while 11 measure more than 100 miles. The longest, that from Sca Fell to Slieve Donard, is 111 miles; the mean length of the whole is 35·4 miles, and their sum 206,710,000 feet, or about ten times the earth's radius. The primary triangulation is subdivided, usually with 12-inch theodolites, into smaller or secondary triangles, the sides of which are from about 10 to 15 miles in length; and these, again, as the survey progresses, are broken up into tertiary triangles, with sides of about a mile. It is within these last that the chain-surveyors afterwards work. For connecting the more distant stations of the primary triangulation, a revolving plane mirror, called the "heliostat," was used, for the purpose of reflecting the sunbeams from the point to be observed towards the far-off station, where the observers were constantly on the watch for the bright star-like point of light. Lines of immense length can be obtained in this manner, if only the stations at either end are sufficiently elevated. The process, however, proved extremely tedious, days, and even weeks, sometimes passing before the looked-for gleam was seen; "more than a month often elapsed between consecutive observations of very distant points."

Vertical as well as horizontal angles were observed during the triangulation, and with an accuracy no less minute. The height, for example, of Ben Muich Dhui, the loftiest but one of the Scotch mountains, as determined in this manner, was 4,295·60 feet; its height as afterwards found by spirit-levelling was 4,295·73 feet, the difference being only ·13 feet, or about an inch and a half.

Lofty towers and hill-tops were most generally chosen for the great trigonometrical points. In setting to work at an observing station, the chief desideratum was to get a firm foundation for the instrument—sometimes a task of great difficulty, especially at stations situated on the moors and bogs. In order that tremors might not be transmitted to the theodolite, it was in all cases isolated, generally by the construction of two independent sets of framework or scaffolding over the station, one inside the other, the inner one to carry the instrument, the outer for the observatory and for the observers to stand upon. Sometimes the scaffolds occupied difficult and dizzy positions, and great skill and ingenuity were necessary in constructing them. The wonderful "crow's nest" which stood for months over the cross of St. Paul's must be in the recollection of many of our readers. In the flat Eastern counties especially, instances of high scaffolding were numerous. One of the most remarkable was the station on Thaxted Church, the tower of which is 79 feet high, and surmounted by a spire of 93 feet, making a total of 172 feet above the ground. The outer scaffold, for the observatory, was in this instance carried from the base to the top of the spire, while that within, for the instrument, was raised upon timbers passing through the spire at a point 139 feet above the ground. Thus, the theodolite, at the height of 178 feet, was completely insulated, and not affected by the movements of the observer or by the action of the wind on the observatory. Did space permit, we might give many other interesting details of the history of the triangulation, and of the difficulties, hardships and dangers which were frequently encountered. But we must now leave this part of the subject, and pass on to consider some of the larger questions in geodesy which the Ordnance Survey has helped to solve.

Of the series of scientific works which have been issued by the department during the last thirty years, the most remarkable is the "Account of the Principal Triangulation," by Captain (now Lieut.-Col.) A. R. Clarke, C.B., R.E., a mathematician of the highest attainments. In this ponderous volume, published in 1858, are contained details of all the trigonometrical and astronomical observations and computations made in connexion with the triangulation, as well as calculations of the figure, dimensions, and mean specific gravity of the earth, as derived therefrom. During the progress of the triangulation, the latitudes of thirty-two of the trigonometrical points had been found with the utmost accuracy, by observations with Ramsden's and Airy's large zenith-sectors, the latter of which was made expressly for the Survey. From the data afforded by the triangulation, Captain Clarke deduced the distances between the arcs of parallel passing through these latitude stations, and thus found the length of an arc of meridian of about 10°, extending from the Shetlands to the Isle of Wight. He then determined that the figure of the earth which would best correspond with the surface of Great Britain would be a spheroid of revolution with an equatorial semi-axis of 20,927,005 feet, a polar semi-axis of 20,852,372 feet, and an ellipticity of $\frac{1}{280.4}$. Also, by combining with the English arc nine of the best measured arcs of meridians in other parts of the world—those namely of Peru, India (2), France, Hanover, Denmark, Prussia, Russia and Sweden—he found, as the elements of the spheroid which most nearly represented all the geodetic measurements, equatorial semi-axis 20,926,348 feet, polar semi-axis 20,855,233 feet, ellipticity $\frac{1}{294.26}$.* Owing, however, to small corrections, consequent on the final results for latitudes of stations in the Russian arc, the above elements were slightly modified in 1861, the corrected values becoming, equatorial semi-axis 20,926,329 feet, polar semi-axis

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* A most valuable series of Geodetical Tables, founded on these elements, were published at Southampton, in 1858.

20,855,239 feet,* ellipticity $\frac{1}{294{\cdot}36}$. Even this result was not final; it depended on old comparisons between the standards of length of our own and foreign countries, and, as we shall presently see, has since then been modified again.

By 1860, the trigonometrical surveys on the Continent had made such progress that it became possible to have the triangulations of France, Belgium, Prussia and Russia, and our own, connected with one another, with the view of finding the measured length of an arc of the 52nd parallel of latitude, extending from Valentia on the west of Ireland to Oursk on the River Ural, that is, through about 75° of longitude, or more than one-fifth of the circle of the globe on the parallel of 52° N. A proposal to this effect, which emanated from the Government of Russia, at the instance of M. Otto Struve, the Imperial astronomer of that country, was acceded to by the Governments of France, Belgium, Prussia and England; the object, it need hardly be explained, being to test the value of the earth's figure and dimensions as previously obtained from *meridional arcs*, by a comparison of the measured length of this great *arc of parallel* with the angular difference of longitude between its extremities, which could now be very accurately determined with the help of the electric telegraph.

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* All the above measures are given in feet of the Ordnance 10-feet standard bar, O_1, at 62° Fahr., which have a minute error; 868,055 feet of O_1 being equal to 868,056 English standard feet.

The connexion with the French triangulation which had been effected by General Roy in 1786 was insufficient for this new purpose, having been made only with the object of connecting Greenwich with Paris, and not directed eastward.

Accordingly, in May, 1861, Captains Clarke and Trench, and Serjeant-Major Steel, R.E., with a small party of Engineers, were selected by Sir Henry James for the task of connecting the trigonometrical points on our south-eastern coast with those on the opposite side of the Channel. Observations were taken from four English and seven French and Belgian stations, three of the large theodolites used in the great triangulation being employed for the purpose. A separate party of French observers, using the same stations and measuring the same angles as the English, were similarly engaged; thus, the whole operation was done independently, in duplicate, by observers from both countries. The English party finished their work in January, 1862, after many difficulties and delays, consequent upon the erection of high scaffolds over several of the continental stations, the tempestuous weather during the latter part of the time, and the frequent fogs and haze which hung over sea and land.

The proposed measurement of this great arc of parallel now suggested to Sir Henry James the importance of a re-comparison of the standards of the several nations engaged in it. Obviously, without a very exact knowledge of the relative lengths of the various national units of measure, it would be impossible to obtain a precise result, or, in other words, to express the length of the arc accurately in terms of any one of the units. Belgium, Prussia and Russia were therefore invited by our Government, on the recommendation of Sir Henry James, to send their standards to Southampton, and Captain Clarke, with Quartermaster Steel and Corporal Compton, R.E., as his assistants, was entrusted with the task of carrying out the necessary comparisons of these standards with our own, and with one another. Altogether, about a dozen bars of various kinds, including some from India, were submitted to comparison in 1864-5. The work was one which required an extraordinary amount of patience and diligence, and of scientific care and skill. The observations were very numerous, and of the most delicate kind, and were made by means of a special apparatus, in a building specially constructed for comparison purposes. An elaborate account of the whole process, with calculations and results, was drawn up by Captain Clarke, and published in 1866,* and gives the relative lengths of nineteen standards and standard bars to the nearest millionth of an inch. Since then, comparisons of the standards of Austria, Spain, Italy, the Cape of Good Hope, and the United States have been similarly made and reduced, but the results are not as yet published.

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* "Comparisons of the Standards of Length of England, France, Belgium, Prussia, Russia, India, and Australia."—*Ordnance Survey Office, Southampton,* 1866.

Captain Clarke's former figures for the elements of the spheroid of revolution which best corresponds to the geodetic measurements had now to be corrected to the newly found lengths of the standards, and with the following results;—equatorial semi-axis 20,926,062 English standard feet, polar semi-axis 20,855,121 feet,* compression $\frac{1}{294 \cdot 98}$. But, in further calculations as to the form of the equator corresponding to the measured arcs of meridians, he found that the earth has three unequal diameters; the equator, in fact, is slightly elliptical, its ellipticity being $\frac{1}{3269 \cdot 5}$; and the lengths of the earth's three semi-diameters are as follows:—

	FEET.
Longer semi-diameter of equatorial ellipse	**20,926,350**
Shorter " "	**20,919,972**
Polar semi-diameter " "	**20,853,429**

Mean compression=$\frac{1}{299 \cdot 67}$.

This is undoubtedly the best determination yet made, but it must be held as liable to further modification when the calculations, now in progress, for finding the length of the arc of parallel between Valentia and Oursk are finished. The longer diameter of the equatorial ellipse was found to be in longitude 15° 34′ E., and the shorter in longitude 105° 34′ E., the meridians of which, as Sir Henry James has pointed out, coincide approximately with the most remarkable features of the globe.

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* Showing an increase of about $\frac{9}{10}$ths and $\frac{5}{10}$ths of a mile, respectively, upon the two diameters as formerly computed by the Astronomer Royal.

It would be difficult to over-estimate the importance to geodetical and astronomical science of the accomplishment of these two great works—the connexion of the various national triangulations for the measurement of an arc of parallel, and the comparisons of standards of length. In a paper read before the Royal Society in 1866, Sir Henry James thus ably sums up the points and advantages of the case:—

"Before the connexion of the triangulations of the several countries into one great network of triangles extending across the entire breadth of Europe, and before the discovery of the electric telegraph, and its extension from Valentia to the Ural Mountains, it was not possible to execute so vast an undertaking as that which is now in progress. It is, in fact, a work which could not possibly have been executed at any earlier period in the history of the world. The exact determination of the figure and dimensions of the earth has been the great aim of astronomers for upwards of 2000 years; and it is fortunate that we live in a time when men are so enlightened as to combine their labours to effect an object desired by all, and at the first moment when it was possible to execute it."

The data for ascertaining the earth's mean specific gravity were arrived at by investigating the amount of the deflection of the plumb-line at Arthur's Seat, near Edinburgh. In 1854, observations for latitude were taken at the north and south ends of this mountain, and on its summit. A comparison between the astronomical differences of latitude, thus obtained, and the measured terrestrial differences, furnished data for finding the attraction of the mountain on the plumb-line, and a ratio was thence deduced between the specific gravities of the mountain and of the mass of the earth. Then, the specific gravity of the mountain having been computed from its geological structure to be 2·75, that for the earth was found to be 5·316.*

Later comparisons between the astronomical and geodetical measurements of the Survey have led to another very interesting discovery. Serious discrepancies were found to exist, in localities where there was nothing *above* ground to account for them, plainly indicating that the plumb-line and the levels of astronomical instruments are sometimes largely affected by masses of irregular density, or possibly large cavities, *below* the surface. At Cowhythe, in Banffshire, disturbance of this kind was found to be so great, amounting to about 10″, that a series of observations was taken with the object of tracing it out. The exact results have not yet been published; but it appears, from Sir Henry James's remarks in his annual reports, that the observations point to the existence of some very large and dense mass of matter beneath the surface, to the south of Cowhythe; and that this investigation, like a similar one made by M. Otto Struve, near Moscow, goes to prove that we cannot rely on observations taken for latitude and longitude at any particular point on the surface of the earth, until we have satisfied ourselves by observations at surrounding points that there is no hidden cause of disturbance.

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* From similar observations at Schehallion mountain, Hutton had previously found the earth's mean specific gravity to be 4·95. From experiments on the attraction of balls, Cavendish obtained 5·45; Baily, 5·67; Reich, 5·44. The Astronomer Royal, from experiments with pendulums on the surface of the earth and at a great depth, obtained 6·55.

Such is an outline of the chief problems in geodesy, to the solution of which the Ordnance Survey has contributed so much, and which cannot fail to interest, not only astronomers, to whom the earth's dimensions and specific gravity serve as units for measuring the distances, magnitudes, and specific gravities of the heavenly bodies, but scientific geographers of all countries. We will now proceed to describe the organization of the Survey Department, and the various processes followed in the actual survey and preparation of the maps.

ORGANIZATION OF THE SURVEY DEPARTMENT.

In 1870, the Ordnance Survey, originally under the control of the old Board of Ordnance—whence its somewhat mystifying name—and latterly under that of the War Office, was transferred to the Office of Works. The one-inch military map of the kingdom, which had been about eighty years in progress, was finished in that year, and it was no longer thought desirable to include the cost of a cadastral survey in the War Office estimates. The organization of the department has, however, been carefully preserved, its essential feature being the combination of military and civilians, on a plan which has been found to answer well hitherto, and by means of which the work is done cheaply and methodically. At present, the survey force consists of about 2174 persons, including twenty officers and four companies of Royal Engineers, and about 1700 civilian assistants, labourers, and chainmen. Subdivision of labour is carried out on the survey to its fullest extent, the force being divided into sections for each separate branch of the work; chances of error are thus reduced to a minimum. The head-quarters of the whole department are at Southampton, where the maps and plans of Great Britain are published, and where all the trigonometrical and other calculations are made. The six-inch sheets of Ireland, however, are printed for sale at a similar, though smaller, establishment in Dublin, where also the revision, now in progress, of the Irish map is carried out upon the plates, and where plans for the Landed Estates Court are drawn as required. The rest of the survey force is distributed over the kingdom, in fourteen sections or "divisions," each consisting on an average of about 100 men, superintended by an officer, and engaged in the actual operations of the survey. To one division, with its head-quarters in London, is assigned the duty of ascertaining the exact course of the county, hundred, parish and other public boundaries in England; one, under Lieut.-Col. Clarke, C. B., is engaged in the tertiary triangulation, which immediately precedes the chain-survey; another, with its head-quarters in Dublin, carries on the revision of the six-inch map of Ireland; a fourth is employed upon the levelling, contouring, and hill-sketching of Scotland; a fifth upon the corresponding duties in England and Wales; and nine divisions in different parts of Great Britain execute the detail surveys, and prepare the manuscript plans.

DETAIL SURVEY, AND PREPARATION OF MANUSCRIPT PLANS.

Let us now briefly sketch—it can be but a sketch—the various processes which are performed before the maps come into the hands of the public. We will suppose, for example, that an order has been given for the survey of Dorsetshire on the $\frac{1}{2500}$ scale, and that the secondary triangulation of that county has been finished. A party of observers, with seven-inch theodolites, is at once sent into the district which is to be first taken in hand, in order to prepare the minor triangles for the detail surveyors. For this purpose, the stations of the primary and secondary triangulations are used to fix a large number of intermediate stations, the positions of which are so chosen on the ground that they may be visible from one another, and form well-shaped triangles with sides of something like a mile in length. Small whitewashed beacons or poles, doubtless familiar objects to many of our readers, are erected over all the stations; and the observations, as finished, are sent to Southampton, where the sides of the tertiary triangles are calculated to the nearest tenth of a foot; and where also the co-ordinates of the trigonometrical points are computed with reference to the sheet-margins, so that they may be afterwards laid down easily on the paper. Parties of "perambulators," or boundary-surveyors, are at the same time at work in the district, finding out the course of the public boundaries,* and preparing outline sketches from which the chain-surveyor may be afterwards able to identify and fix the various boundary marks. A detail-survey "division" is now sent, let us suppose, to Dorchester, where its head-quarter office is established; and parties of surveyors, each superintended by a non-commissioned officer of the Engineers, are detached to towns and villages in the district about to be surveyed. Their first duty is to trace out and chain the sides of the minor triangles, noting in their field-books, as they go along, the positions of all fences, streams, and other objects which they cross, and leaving ground-marks or "piquets" at the points which may be most convenient for starting afterwards with the internal lines of the survey. The measured lengths of the sides of the triangles are now sent to the office, for comparison with the computed lengths, and when they are found sufficiently correct the detail-survey is proceeded with. This survey is made almost wholly by the method of right lines, one much more simple, and less liable to error, than that of "traverse-surveying," which is therefore only resorted to in emergencies, and in the highlands and uncultivated districts. By the right-line system, the surveyor simply chains a net-work of straight internal lines across and within his triangle, taking offsets right or left, as he goes along, to every object on the face of the country, and noting all measurements in his field-book. His skill and judgment are shown by his selection of these internal lines, which should be so directed that each may answer for the survey of as many as possible of the features to be mapped, and that the survey of the triangle may thus be completed with the least possible number of lines. The quality of the surveyor's work is subjected to a very simple test in the office. The whole system of lines forms a sort of geometrical puzzle, and the plotter, having laid down the sides of the triangle carefully on his paper, is at once able to find by actual measurement whether or no the internal lines will fit in in their proper places, and can tell whether any mistakes have been made, in which case the faulty work is sent back to the surveyor to be remeasured. When the line-survey has been thus checked, and correctly finished, the rest of the contents of the field-book are plotted in pencil in the office, and a skeleton or outline drawing of the country is thus produced. This is now traced, in sections of a convenient size for further use in the field, and the tracings are placed in the hands of "examiners," whose duty it is to go over the ground, verifying the surveyors' and plotters' work, testing the boundaries, supplying the nomenclature, and the various characteristics, such as woods, parks, gardens, moors, antiquities, &c., inserting anything that may have been omitted, distinguishing the metalled roads from those which are unmetalled, and noting the state of cultivation of the various enclosures, whether arable, wood, pasture, waste land, and so forth. With the completed tracings as a guide, draughtsmen in the office now transform the plotted pencil plans into finished drawings. The draughtsmen of the Ordnance Survey are justly renowned, and the 25-inch plans form admirable specimens of their skill; indeed, those done by the best workmen could hardly be excelled. All the plans are drawn on one uniform system, the same symbols, colours, types, and thickness of lines being adopted throughout the survey. Most of the work is done by hand, but woods, figures, and nearly all of the names are stamped by lads on low rates of pay, and the more expensive labour of the skilled draughtsmen is thus economized.

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* The public boundaries are pointed out to the surveyors by properly qualified persons called "meresmen," who are appointed for each parish, or division thereof, by the Justices in Quarter-Sessions in England, and by the Sheriffs of counties in Scotland. The term "meresman" is most probably derived from the Anglo-Saxon *gemǽro* "boundaries;" or possibly from the Saxon *mearc*, a "mark" or "boundary."

The next process is to compute the areas of the enclosures as shown on the plans. This is done with the "computing scale," a beautiful and simple contrivance, invented by an *employé* of the department. By means of it the acreage of each enclosure is calculated separately; and, as the sum of all the areas in each full sheet should be 960 acres, a ready check is thus furnished upon the accuracy of the computer's work. In consequence, however, of the daily expansion and contraction of the paper, absolute accuracy can seldom be attained, and a small percentage of error, about 0.2 per cent., is allowed, and is afterwards distributed throughout the parcels in proportion to their area. The acreages are calculated and made up separately for each parish, every enclosure having a reference number stamped upon it. An area-book of the parish is then compiled, in which the acreages (to the one-thousandth of an acre) and states of cultivation of the several enclosures are entered opposite to their respective reference numbers, an abstract of the whole being given at the end of the list: the area-book, thus finished, is afterwards printed, and published with the plans.

As every landowner is primarily interested in the acreage of his property, it may be well at this point to explain the principles upon which the Ordnance Survey areas are computed. It must be obvious to the least experienced reader that, in a survey founded on a system of triangulation, none but *horizontal* measurements and *horizontal* areas can be given. To attempt to roll the country out flat—in other words, to take account of inclinations of the ground in the delineation of features, or the calculation of areas—would be to defy all principles of accurate map-making, and to pass beyond all limits by which areas can be checked. The horizontal system, therefore, as the only one applicable to a general national map, is that which has been adopted for the Ordnance Survey. We believe, moreover, that it is the best and truest system. *The produce of land, and therefore its real value for sale, or letting, or taxation, are, if we mistake not, directly proportional to its horizontal area.* Then, as regards tillage and labour on the land, it can hardly be doubted that both employers and employed would benefit in the long run by adopting as the final basis of agreement the areas given by the Ordnance maps. They would certainly gain in the prompt settlement of disputes, and in the saving of the sums now so constantly paid for land-measurements to local surveyors. And although the labourer or ploughman who works by the acre may naturally prefer to be paid according to the superficial rather than the horizontal measurement of sloping land, and will doubtless imagine, when he comes to think about the matter, that he is a considerable gainer by that mode of reckoning, the difference between the two is in reality extremely small, very much smaller, indeed, than is generally supposed, seldom exceeding two or three per cent. on the steepest slopes that can well be cultivated. For example, a 10-acre field, on a slope of 1 in 4, measures about 9·7 acres on the horizontal plane, the two areas thus differing by no more than about three per cent. While on the subject of the acreage of estates, it is necessary to explain that private boundaries are not shown *as such* on the Ordnance plans, that is to say, no reference whatever is made to rights of property. This would need special machinery, and lead to difficult and protracted enquiries. All natural and artificial divisions are, however, delineated; and, as the boundaries of property nearly always follow the course of such divisions, landowners are at once able to identify their own estates and holdings on the plans, and to ascertain their own acreage from the area-books.

To complete the plans, it now only remains to mark upon them the relative heights of their various parts. Every one has noticed the bench-marks,* , cut upon many of the milestones, walls and gate-pillars along our chief highways in all parts of the country. They are the permanent marks of the Ordnance Survey system of spirit-levelling, a system which is so perfect and comprehensive as to merit a short digression for the purpose of explaining it. Just as the principal triangulation forms an accurate framework within which the minor triangles are afterwards laid out, in like manner, a series of lines of principal or "initial" levelling, extended over the kingdom, furnishes a definite basis for a system of interior lines of minor or "detail" levelling, which, as the survey progresses, are carried along nearly every road in the country. The lines of the principal series, which were begun in 1839 and finished in 1861, were executed with great minuteness and care. They so often intersect and meet one another that numerous checks were thus afforded upon the accuracy of the work. Small discrepancies were of course absolutely unavoidable, and these were treated as a whole in each of the great series of levels for England-and-Wales and Scotland, and were rigorously worked out by the method of least squares, so as to make each series by itself perfectly correct and consistent. These reductions proved tasks of great mathematical difficulty; that, for example, of the English series ultimately involved the solution of a system of equations with ninety-one unknown quantities. In connexion with the trunk lines of levelling, tidal observations were made at a number of stations round the coasts of Great Britain, for the purpose of finding the relative heights of the *mean tide levels* at all the stations, that is to say, of the levels corresponding to the mean or average height of the sea at each station, as derived from long series of observations made at small equidistant intervals at all times of the tide. The mean tide levels were found to differ considerably at the various stations, the extreme difference amounting to more than thirty inches. An average of the whole was ultimately taken as the *mean level of the sea* for Great Britain. This average, however, could not be known until all the tidal observations had been made, and all the levelling finished and finally computed; it was the very last bit of information that could, in the nature of things, be ascertained. Meanwhile, in order that the publication of the plans with levels might not be delayed, it was necessary to adopt some fixed datum-level, to which the whole system of Ordnance Survey heights might be referred. For this, the mean tide level at Liverpool, which, according to the most trustworthy determination, is 7·47 inches below the mean level of the sea as since ascertained, was chosen. Every altitude marked upon the plans, from Cape Wrath to the Land's End, is accordingly expressed with reference to this one Liverpool datum, and is therefore strictly correct in its relation to every other such altitude, no matter how far apart the points may be. In a similar manner, a mean level of the sea was found for Ireland. This, however, was not entered upon till after the engraving of the sheets; and the levels on the Irish maps are all given with reference to a datum previously fixed upon, viz., low-water of spring tides at Poolbeg Lighthouse, in Dublin Bay, which is 8·094 feet below the mean level of the sea round the coast of Ireland as since determined.

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* I have been unable to obtain any satisfactory information as to the origin of this term, and I cannot even guess at it. The use of the barbed head, (or "broad arrow," as it is generally termed) as the Ordnance mark appears to have sprung from the fact of its having been the crest of a former Master-General of the Ordnance: such at least is the not improbable explanation elicited in "Notes and Queries" for December, 1872, by the enquiry of a friend.

The detail-levelling is carried out, as we have already intimated, contemporaneously with the progress of the cadastral survey. Starting from marks on the initial series, lines are run along nearly all the turnpike and parish roads, and bench-marks cut at intervals of about a quarter of a mile. The whole of the bench-marks of the initial and detail levelling are shown in position on the 25-inch manuscript plans, and their heights given to the nearest tenth of a foot. Surface-heights, to the nearest foot, are also marked on the plans, at frequent intervals between the bench-marks.

The manuscript 25-inch plans of our district are now finished, with every object shown in its true position and character, the names correctly given, the trigonometrical points marked, the public boundaries defined, levels scattered over the surface, and the plots all numbered in correspondence with the parish area-books. Thus complete, and having been finally examined on the ground by the officer in charge, they are forwarded to Southampton for publication.

In the survey and mapping of towns, on the larger scales, the processes followed are in all respects on the same principle as those we have described for the rural lands, though of course more minute and tedious. A number of extra trigonometrical points within the towns are fixed from surrounding stations, but, from the nature of the work, it is generally necessary to make the surveys in "blocks" or multagonal figures, rather than in triangles. The levels are more numerous in towns than in country work, lines of levelling being carried along every street; while bench-marks and surface-heights are much more frequently given. No attempt, however, is made to calculate the acreages of the innumerable plots, and the area of each town as a whole is alone computed.

PUBLICATION OF PARISH AND TOWN PLANS.

The parish and town plans, after having been once more thoroughly examined at Southampton, are published by zincography, a process which was adopted on the Ordnance Survey in 1855, and which, though closely resembling lithography, is yet in several respects superior to it. The work turned out is equally good by either process: but, while a lithographic stone of the area necessary for the Ordnance plans is about four and a half inches thick, costs about £7., and weighs 450 pounds, thus requiring four men to lift it, a zinc plate of equal surface is but $\frac{3}{16}$ths of an inch thick, costs only 16*s*., and weighs no more than 60 pounds, so that it can be easily carried by one man. The zinc plates also wear extremely well, and are less liable to fracture than the lithographic stones. Those used on the survey are of the best Silesian zinc, and the surface is prepared by successively scraping with a razor-blade, grinding with pumice-stone and water, smoothing with steatite or "water-of-Ayr stone," and graining with moulding-sand. The outline of the manuscript plan is traced in lithographic ink, on tracing-paper thinly coated with starch or paste. This, for the sake of cheapness, is done by boys, but the writing and characters are added by a superior workman; boys also stamp the woods, figures, &c. The remaining processes of transferring the tracing to the zinc, and printing the impressions, are exactly the same as in lithography, except that a different "etching liquid" is used for the zinc. Each parish on the $\frac{1}{2500}$ scale, and each town on the $\frac{1}{500}$ scale, is published separately, as soon as the sheets are ready. For the first edition, it is usual to take from 30 to 100 impressions of the plans, according to the probable demand. After this, the zinc plates are cleaned off, and re-prepared for other sheets. It is found to be cheaper and more convenient to do this, and to make fresh tracings from the manuscript plans when a second edition is wanted, than to keep the plates idle meanwhile. A transfer on zinc will however print more than 1000 copies, if required, without sensible deterioration. The printed sheets, after having been dried and pressed, are passed on to boys, who colour the houses, roads, and water. The edition is now ready for sale. The publication of the zincographed plans, at Southampton, is under the excellent immediate superintendence of Lieut.-Col. R. M. Parsons, R.E., who also has charge of the photographic and photozincographic branches, the former of which we will now describe.

Six-inch Plans.

Photography is largely employed on the Ordnance Survey as a substitute for the skilled labour of draughtsmen. Formerly, the reductions of plans from one scale to another were made with the pentagraph or eidograph, and were both tedious and costly. But, when it was proposed to adopt four scales for the plans of the national survey, it became evident to Sir Henry James that, unless some method could be devised by which reductions might be effected much more rapidly than by any means then known, the publication of the maps would proceed too slowly, and its cost be too great, to satisfy the public. He gave his close attention to the subject, and was rewarded with success. At the Paris Exhibition of 1855, he instituted experiments to test the possibility of reducing plans accurately by photography, and the results were so nearly satisfactory that he was led to make further trials at Southampton, where the process was soon improved, and ultimately brought to perfection. It was at first alleged, in Parliament, that the reduced plans would be inaccurate, owing to distortion produced by the lens. But a scientific committee, of which the late Sir Roderick Murchison was chairman, reported in 1859 that the greatest deviation in any part of the plans from perfect accuracy does not amount to the $\frac{1}{400}$th part of an inch in the angle of the rectangle, and that even this minute error is not cumulative. Manifestly, such an error is quite insignificant, and for all practical purposes vanishes; its maximum amount can, in fact, be scarcely perceived, and is much within the limits of the expansion and contraction of the paper under ordinary atmospheric changes.

The photographic process was therefore finally adopted for the reduction of plans from the $\frac{1}{500}$ to the $\frac{1}{2500}$, and from the latter to the six-inch scale; it insured an accuracy previously unattainable, and moreover effected, in addition to an immense saving in time, a saving in money which is calculated at not less than £35,000 on the whole cost of the survey.

The processes by which the plans on the $\frac{1}{2500}$ scale are prepared and published having been already described, let us now trace the steps followed in the reduction and engraving on copper for the six-inch sheets. In the first place, the $\frac{1}{2500}$-scale plan which it is proposed to reduce is fixed to an upright board in the photographic room, which can be adjusted to any required height. Opposite to it is the camera, placed on a table which travels on a small tramway on the floor, and furnished with means of lateral and vertical adjustment. A rectangle of the size of the required reduction, viz., nine inches by six inches, being marked on the ground glass of the camera, the instrument is moved backward or forward, and otherwise adjusted, until the lines of this rectangle exactly coincide with the marginal lines of the image of the plan on the board as seen through the camera; a negative is then taken and printed from in the ordinary manner. The print is now "touched up," for the future guidance of the copper-plate engraver, by penning in faded parts, rewriting the altitudes, and colouring the parks, woods, water, houses, &c., with distinctive shades. It is next traced, in outline only, with lamp-black, on very thin paper; and the tracing is then transferred in the usual way to the waxed surface of a copper plate, on which the sheet-corners and trigonometrical points have been previously scored by machine.* A six-inch plan contains the same area as sixteen plans on the $\frac{1}{2500}$ scale. Sixteen equal rectangles, each corresponding to the area contained in a single photograph, are therefore ruled in faintly on the waxed copper-plate, so that each tracing, as it is transferred, may be laid accurately in its true position. The plate is now ready for the engraver.

The reductions by photography of town plans from the $\frac{1}{500}$† to the $\frac{1}{2500}$ scale (with the view to representing the towns, thus reduced, on the parish plans) are made in the same way as those for the six-inch sheets; the prints are then traced in greasy ink, in spaces left for them on the tracings from the manuscript $\frac{1}{2500}$ plans, which, as described in the preceding section, are afterwards transferred to zinc plates for publication.

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* It will be obvious to the reader that when, as in the case of the uncultivated districts, the survey has been drawn in manuscript on the six-inch scale only, a tracing can be taken direct from the plan, and transferred to the copper, the intervention of photography being now unnecessary.

† Or from the scales of five feet or ten feet to a mile, on one or the other of which the towns were generally drawn and *engraved*, prior to the introduction of the $\frac{1}{500}$ scale and the publication of the town plans by zincography.

In the engraving department at Southampton, presided over by Colonel Cameron, C.B., Sir Henry James's able second in command, every process is resorted to by which the work can be cheapened and expedited, and its perfectness and uniformity insured. Steel punches are used for the trees, woods, bushes, and figures, a ruling-machine for shading the buildings, and a dotting-machine for the parks, sands, and mud; and by means of these, and of elaborate subdivision of labour in other parts of the work, an almost perfect similarity of style and finish in all the plans is obtained.

One very useful feature in the six-inch plans, as now published, is that the degrees, minutes, and seconds of latitude and longitude are marked upon the margins. Thus, not only can the geographical position of every spot in the country be exactly found, but, in cases where other means of description fail, boundaries of properties may be defined and identified by the latitudes and longitudes of their extremities. Still more valuable is the information as to the form and undulations of the surface of the country which is given by means of lines of identical elevation, technically called "contours," —that is, a system of lines representing the intersections with the surface of horizontal planes at certain stated vertical intervals—which are traced out over all the sinuosities of the ground, and afterwards engraved on the plates: contour lines may be familiarly illustrated by the horizontal traces left upon a beach by the receding tide. For the Ordnance Survey, the contours are given at 50, 100, 200, 300 feet, and so on up to 1000 feet, above the Liverpool datum. In this way, the relative heights and slopes of the surface are indicated with considerable minuteness and accuracy, and without that tendency to obscure the other details which accompanies the ordinary methods of representing ground by hill-shading. The contours are inserted by field-workmen, on the ground itself, on prints from the six-inch photographs. Arriving at the spot where he is to begin, the contourer, who is provided with a "contouring theodolite" and staff, first finds a starting-point on the contour he is required to trace, by levelling up or down to it from the nearest bench-mark shown on the photograph. If, for example, he wishes to run a contour at 300 feet, and the nearest bench-mark is at 305 feet, he levels down five feet from the mark. Having thus found his contour, he follows it out on the ground at the dead level, wherever it leads him, by the help of his instrument, and is able to mark its course on the photograph by measurements to neighbouring objects. In this manner, each contour successively is traced and plotted, constant checks upon the workman's accuracy being afforded by references to the nearest bench-marks wherever the contours intersect the original lines of spirit-levelling. The contour lines, thus marked upon the photographs, are then engraved on the copper plates.

One-inch Maps.

It remains to sketch the processes by which the one-inch maps are made. Photography is not used for the reductions in this instance, the ratio of the reduction being so very great that it is necessary, for the sake of distinctness, to omit some details and enlarge others, conditions which, from its very property of faithfulness in delineation, the photographic process fails to fulfil. A sheet of paper of the required size having been prepared with its marginal lines, and also having had ruled upon it rectangles corresponding in size and position to the several $\frac{1}{2500}$ or six-inch plans which make up the whole area of the sheet, a manuscript drawing, complete in all except the contours and hill-shading, is then made, the required outline in each rectangle in succession being reduced with the pentagraph to the one-inch scale from six-inch photographs of the large-scale plans; or, as in the case of the uncultivated lands, from the six-inch manuscript plans themselves. This drawing is now traced, and transferred in the usual way to a waxed copper plate; the outline, names, and ornament are then engraved.

At this stage of its progress, the plate is electrotyped, and on the duplicate and absolutely facsimile copy of the original which is thus obtained the contour lines and altitudes are afterwards engraved. The hill-features, without contours, are then engraved on the original; and, when these are finished, another electrotype duplicate of this plate is taken, and the geological lines are inserted upon it. So that thus, without any of the engraving having been done more than once, three editions of the one-inch map are issued to the public, one with contours, another with hills, and a third with hills and geological lines.* Electrotyping is not only useful in this manner for making duplicates of the plates in various stages, with a view to furnishing different classes of information. In order to ensure a future supply of perfect impressions, the first electrotype casts in relief—*matrices*, as they are termed—of the plates when in their fresh and unworn condition are put by in store, to be hereafter used for obtaining duplicate plates, to print from when the originals have become worn out by long use. In future, therefore, the public will have no cause to complain, as heretofore, of being occasionally supplied with bad impressions from old and damaged plates. Another great advantage of the electrotype process is the facility which it affords for making alterations on the plates. To erase lines *cut into* the copper is a tedious and difficult process, and likely to injure the rest of the work. But a *matrix* shows the lines in relief, and from this it is easy to *scrape off* obsolete details; a duplicate plate, with the lines in intaglio, being then taken from the altered *matrix*, the engraver is able without difficulty to add the fresh details where needed. It will be readily understood how valuable this process is for the insertion of new railways, roads, and so forth.

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* By an ingenious process, lately devised, the drawings of the hill features, after having been photozincographed, are printed, either in black or colours, from *separate* hill-plates, on impressions from the one-inch outline plates. Thus, maps with the hill-features are issued promptly to the public, almost as soon as the outline plates are ready, and without waiting for the hills to be *engraved*. For a fuller account of this process, *see* "*Ocean Highways*," June, 1873, p. 107.

The hill-features for the one-inch maps are first sketched, in the field, on dry proofs from the six-inch contoured plates. Finished drawings from the field sketch are then made, on cardboard impressions from the one-inch outline plates, and furnished as guides for the engraver to work by. Beautiful and delicate in finish as is all the work of the copper-plate engravers on the Ordnance Survey, there is perhaps no branch in which they so peculiarly excel as in their delineation of hills on the one-inch plates. Certainly, no other map-engravers in Europe produce anything equal to it. Fine graving needles are used to etch in the lines, and the requisite deepening of the tints is given afterwards by a process called "biting in," which consists of exposing the cut lines in the copper to the action of aquafortis, the general surface of the plate being protected by a coating of a substance called "etching ground." The deeper the shade required, the longer or more frequently must the aquafortis be allowed to act; and, at each successive application of the acid, the parts already sufficiently bitten in are protected from further action by painting them with a "stopping varnish." So slow and delicate, however, are these processes that the average progress of the best workmen does not amount to a square inch daily.

PRESENT STATE OF THE PUBLICATION OF THE MAPS AND PLANS.

Of the progress made in the publication of the survey it is impossible to give exact details without a tedious enumeration; but the following short abstract will convey some idea of it:—

In England and Wales.—The four northernmost counties, Middlesex and Surrey, the Isle of Man, and Isle of Wight, nearly all of Flintshire, Kent and Hants, and parts of fifteen other counties, have been published on the $\frac{1}{2500}$ scale; the six northern counties, Isle of Man, and Isle of Wight, and parts of nine other counties, on the six-inch scale; and the six northern counties on the one-inch scale* with hills. In 1871, the tremendous task of drawing the detailed plan of London on the five-feet scale was finished; it is contained in 326 full-sized sheets, about 170 of which have been published. A skeleton plan of the whole metropolis, contained in 821 quarter-sheets, was published some ten years ago. About 140 other towns have also been published on the $\frac{1}{500}$, or the five-feet, or the ten-feet scale.

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* This refers only to the sheets on the *new* projection (*see* p. 14), and not to the original one-inch military map of England and Wales, the *whole* of which is published.

In Scotland.—The cultivated parts of the Isle of Arran, and of about two-thirds of the mainland, including all the south and east except six small counties, are published on the $\frac{1}{2500}$ scale; the Isles of Lewis and Arran, and more than half the mainland, comprising all the south and east parts of the country, on the six-inch scale; the same two islands, together with nearly half the mainland in the south and east, on the one-inch scale with hills; and all the towns (sixty in number), Wick excepted, on the $\frac{1}{500}$, or the five-feet, or ten-feet scale.

In Ireland.—The county of Dublin has been published on the $\frac{1}{2500}$ scale; the whole country on the six-inch scale; the whole of it on the one-inch scale in outline, and about two-fifths of it on the same scale with hills; and forty-nine towns on the $\frac{1}{500}$ or the five-feet scale.

All these maps and plans are supplied to the public at a cost which places them within reach of every one to whom they are likely to be of use or interest. With the new one-inch quarter-sheets of England and Wales, and Ireland, for sale at 1*s* each; the one-inch half-sheets of Scotland at 1*s* 9*d*; the six-inch sheets at 2*s* and 2*s* 6*d*; the $\frac{1}{2500}$ plans at an average price of 2*s* 6*d*, and the town plans at prices of from 2*s* 6*d* to 6*s*, no one will need in future to be without a beautiful topographical map of his neighbourhood, or a perfect plan of his property or holding, be it an estate, a mansion, a farm, a field, or even a cottage. And, although the above scale of prices might possibly be somewhat reduced and simplified, there can be no doubt whatever that, even at the present rates, the public get their full money's worth for their money.

State of the Surveying.

The surveying is, of course, considerably in advance of the publication. Out of the 58,000 square miles which make up the area of England and Wales, very nearly two-fifths have been surveyed, while about one-sixth only has been published on the $\frac{1}{2500}$ scale, and little more than one-fourth on the six-inch scale. The survey is now going on in Berks, Hertford, Essex, Derby, Chester, Denbigh, Glamorgan, Wilts, Oxford, Bucks, and Sussex. Of Scotland, with an area of 30,000 square miles, though but six-tenths have been published, nearly nine-tenths have been surveyed. Ross-shire is the only unfinished county on the mainland, and, if the weather be favourable, it will be finished this year. Hence, Ireland being already completed, there will remain at the beginning of next year nearly three-fifths of England and Wales, besides the Orkneys and Shetlands and most of the western islands of Scotland, in order to finish our great national cadastral survey.

How long this task will take is a question mainly of money, and depends on the sums that may be voted annually by Parliament. The larger the grants, the quicker and also cheaper will the work be. If the progress has until lately been slow, it is because the sums voted year by year were for a long time very small in proportion to the total cost of the work. It is absolutely necessary, however, for the completion of the survey within any given time, or for any given sum, that the amounts of the annual grants, however large or small they may be, shall not vary much from year to year. For while, on the one hand, a large decrease necessitates a reduction of the working parties, and adds materially to the cost per acre of the work, on the other hand, a large and sudden increase is at first equally expensive and unfruitful, since the special skilled labour of the department needs a long course of practical training, and cannot be obtained in a moment. In 1858, Sir Henry James estimated the cost of completing the survey of Great Britain, on the scales now ordered, at about £2,207,000, provided that the grants should be steady and liberal. In 1870, by which time some £740,000 of this amount had been spent in the prosecution of the survey, the figures were again gone into, the result showing that the proportion of work done was equivalent to the sum expended, and thus justifying his former estimate. There remained therefore, in 1870, £1,467,000, as the probable cost of completion. This, at the present steady rate of about £100,000 per annum, will finish the survey some twelve years hence, soon after which we shall probably be in possession of a complete set of topographical maps and cadastral plans of the United Kingdom, of a kind which it is safe to describe as more perfect in accuracy and finish than any hitherto seen in Europe.

REVISION OF THE MAPS, SYSTEM OF SALE, &C.

Without periodical revision and correction, all maps must sooner or later become obsolete and of little use. It will, therefore, be necessary before long* to establish a permanent revision department for the whole Kingdom, to be constantly engaged in bringing the maps and plans up to date. In Ireland, a sub-department of this kind is already in working order. It is considered, by those who are best qualified to form an opinion on the matter, that, on an average, the issue of a corrected edition of the sheets every fourteen or fifteen years will sufficiently meet the public requirements. We may suppose, therefore, that the United Kingdom will ultimately be divided into fourteen or fifteen districts, (each such district to be situated partly in each of the three Kingdoms), and a revision department be maintained on such a footing as will enable it to produce a corrected edition of the maps of one district in each year, and perhaps also to keep small parties constantly at work in the metropolis and its suburbs, as well as in others of our largest and growing cities, and very populous neighbourhoods. The cost of this service has been estimated by Sir Henry James at about £38,000 per annum, of which sum, however, the greater part at least will probably be repaid by the sale of the plans. Thus, though the parent survey is an absolute cost to the nation, it is anticipated that, when this is finished, the Survey Department will thenceforward be nearly or perhaps quite self-supporting.

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* It would seem that it is already time for the revision to be begun in Great Britain. The $\frac{1}{2500}$-scale survey has been in progress for about eighteen years; and fresh editions of the maps of the districts first surveyed, and especially of those parts of North Kent and North Surrey which were done from ten to fifteen years ago, are even now very much wanted.

But, in order that this expectation may be fulfilled, it will certainly be necessary to use all possible endeavours to make the Ordnance maps more accessible and better known to the public than they are at present. As Mr. Francis Galton very truly remarked, when drawing attention to this subject at the recent meeting of the British Association at Brighton:—

"English geographers are justly proud of the

"Ordnance maps, whose accuracy and hill shading "are unsurpassed elsewhere. . . . . It is much to "be regretted that these beautiful and cheap maps "are not more accessible. They are rarely to "be found even in the principal booksellers' shops "of important country towns, and I have never "observed one on the bookstall of a railway "station. Many educated persons seldom, if ever, "see them; they are almost unknown to the "middle and lower classes; and thus, an important work, made at the expense of the public, "is practically unavailable to a large majority of "those interested in it, who, when they want a "local map, are driven to use a common and "inferior one."

Various methods of supplying the Survey maps to the public have from time to time been adopted. Prior to 1866, 150 agents in the chief towns in the kingdom possessed the right to purchase maps, for sale to the public, from the depôts at Southampton and Dublin, at a discount of 25 per cent. Since 1866, and till quite recently, this right has been restricted to six chief agents, viz.: four in London, one in Edinburgh, and one in Dublin, who received a discount of 33⅓ per cent. on the sale price, and through whom alone the trade and the public could be supplied. To this system it was not unfrequently objected that country booksellers were discouraged from competition, that Government lost money by the change, and that, however great might be the zeal and disinterestedness displayed by the chief agents the maps and plans were not brought as prominently before the public as they might have been. Within the last three months, however, the former plan, or rather an extension of it, has been reverted to; the sole rights of the chief agents have been withdrawn, and a large number of booksellers in all parts of the kingdom have been appointed agents, all alike receiving a discount of 25 per cent. Government depôts have also been established in London, Edinburgh, and Dublin, for the readier supply of maps to the agents or the public. Some years ago, Sir Henry James, if we are rightly informed, drew up and pressed unsuccessfully on the Government a scheme for establishing Ordnance map agencies at a number of the chief post-offices throughout the country, regard being had, in selecting the offices, both to their distances from one another and to the comparative density of the population that each would have to serve. Mr. Galton, in the speech from which we have quoted, made suggestions of a similar kind. It would thus appear that there has hitherto been some difference in opinion on the subject, as well as in the course taken by successive Governments. The question is one of considerable importance both to Government and the public, demanding thorough investigation and trial, and the final adoption of that system, whichever it may be, which is found to combine the largest sale of the maps with the greatest benefit to the country. It cannot for one moment be maintained (as has been done), in the consideration of this question, that Government ought not to press the sale of their maps, for fear of interfering with private trade interests. As Mr. Galton points out, "The nation has deliberately chosen to undertake the survey, on the ground that no private enterprise could accomplish it satisfactorily." The right course to follow is that which will best render the Survey popular, and its publications easily and cheaply accessible; so that the beautiful maps and plans for which the country has paid—instead of being half hidden out of sight, or replaced by copies or reductions, no cheaper than the originals, and vastly inferior to them in accuracy and finish—may be freely circulated amongst all classes of the public.

MISCELLANEOUS WORK OF THE SURVEY DEPARTMENT.

We have thus far dealt chiefly with the main subject—the surveys of the United Kingdom, and the geodetical operations immediately connected with them—and have made no mention of the subsidiary services which the Survey department is frequently required to perform. To the importance and miscellaneous character of these services Sir Henry James's annual reports bear ample testimony. There could, indeed, be no better proof of the usefulness and resources of the department, and the growing appreciation of the national survey, than that which is afforded by the numerous demands upon the office at Southampton, for maps and plans and various kinds of aid, which are constantly being made from all quarters of the kingdom. Nearly every Government department, and public bodies throughout the country, have thus, in some way or other, within the last few years, derived help and information from the Ordnance Survey; and their demands are steadily increasing.

To illustrate this by a few examples culled from the annual reports, we may cite the large surveys (nearly 700,000 acres) made for the War Department between 1858 and 1863, for designing works for the defence of the country, besides surveys of a similar kind in Canada and Gibraltar, and plans for military purposes in many other parts of the world; maps of the river-systems and catchment-basins in England and Wales, for the Royal Commission on Water Supply; plans of the high-water line and areas of foreshores in the United Kingdom, for the Commissioners of Woods and Forests; plans for the Landed Estates Court in Ireland, as fully described in the early part of this pamphlet; plans of the Borough and other boundaries in England and Wales, for the Parliamentary Boundary Commission of 1866; and a large number of plans, with boundaries, areas, and other information, for the Census Commissioners of 1870. To these may be added miscellaneous surveys and plans for the Foreign Office and the Admiralty, the Rother Levels Commissioners, the Post-Office Telegraphs, the Inclosure and Tithe Office, the Army Medical Department, and other bodies too numerous to mention, together with the surveys of a large number of towns for the Board of Health; and, lastly, the surveys just completed, as part of the cadastral survey, for the Thames Valley Drainage Commissioners. It is surely unnecessary to swell further this catalogue of examples in proof of the wonderful utility of the Survey department and the multifarious nature of its duties, as well as of the essentially national character of a survey that can thus fulfil so many public purposes.

The department is also a school for topographers engaged in other parts of the world. At different times, parties of surveyors have been trained and equipped at Southampton for the Cape of Good Hope Survey, the Oregon Boundary Commission, and the British Columbian Expedition; and special instruction is frequently given to officers and men engaged in the surveys of our colonies and foreign possessions, and even to officers of the topographical departments of Continental states. The Ordnance Surveys of Jerusalem and Sinai, though semi-official only, and not paid for from public funds, nevertheless owe much of their success, and of the value which is now attached to them, to their connexion with the large and well organized department at Southampton, in which the public justly have perfect confidence; and the Palestine Exploration Fund still gladly draw their working surveyors from the well trained staff of the Ordnance Survey.

PHOTOZINCOGRAPHY.

There is one very interesting branch of work, which, though not directly applied to Ordnance Survey purposes, is largely carried on at Southampton, in the reproduction, rapidly and in large numbers, of facsimiles of special plans and foreign maps, ancient manuscripts, &c., either of the same size as the originals, or to any required lesser scale. We refer to the process of photozincography, invented and brought to perfection by Sir Henry James and Captain A. de C. Scott, R.E., in 1859, which, as its name suggests, combines the accuracy of photography with the facility of printing from zinc plates. Without entering into a detailed description of this now well known process, we may explain, briefly, that it consists of obtaining from a photographic negative on glass a print in greasy carbon ink, which can be transferred to a zinc plate, and printed from in the ordinary way. The main difference, in fact, between zincography and photozincography is that whereas, in the one case, as we have already explained, a *tracing* from the original document, or from a reduction of it, is made in greasy ink, and transferred to the zinc, in the other case, a *photograph*, direct from the original, and therefore free from all errors of the draughtsman's hand, is made to answer the same purpose as the tracing, and to serve for producing an equal number of impressions. Photozincography is thus in some respects superior to zincography, especially for certain kinds of work, and when the original is not too large to be photographed to the required size in a single picture. When the original has to be photographed in parts, and the prints joined before being transferred to the zinc, the process is more troublesome; photozincographs exceeding 3 feet by 2 feet in dimensions have nevertheless, Lieut.-Col. Parsons states, been successfully prepared in this way in the department under his charge. The method also enjoys this advantage, amongst others, over photography—that the impressions from the zinc in carbon ink are not liable to fade, like photographic prints in silver.

It is in the reproduction of facsimiles of rare deeds and ancient manuscripts that photozincography has been chiefly and most successfully employed at Southampton. Thus, in 1860, the Treasury directed that a facsimile copy of that part of Domesday Book which relates to Cornwall should be made by this process; and this was soon followed by the reproduction and publication for sale, county by county, of the whole of that interesting work, which has thus been distributed throughout the kingdom at a low rate of cost. This step proved so successful that in 1864 Sir Henry James suggested to Government the publication, in a similar manner, of a selected series, chronologically arranged, of the State papers preserved in the Public Record Office; with the view, not only of giving the public easy access to the interesting subject matter of the documents, but also of illustrating the change in our language and writing from time to time. This series, consisting of facsimiles—with translations and explanatory notes by Mr. W. Basevi Sanders, Assistant Keeper of Records—of the most curious and interesting of our national records, from the time of William the Conqueror to that of Queen Anne, has been published in four parts. A selection of the National MSS. of Scotland has also been published, in three volumes; and an extremely interesting Irish series is in course of reproduction. In 1870, a photozincographic facsimile edition of the Black Letter Prayer Book of 1636, which contains the MS. notes showing the alterations made in the authorised version in 1661, was published for the Ritual Commission; and in 1870-71, two such facsimile editions of twenty pages of the Parker Register in Lambeth Palace library were printed for the work entitled *Ordinum Sacrorum in Ecclesiâ Anglicanâ defensio.* Altogether, so remarkable has been the success of the photozincographic process that it is now in general use in this country, as well as in India, America, and the chief States of Europe. It is indeed hardly possible to estimate the value of the many uses to which photozincography may be applied. Exact identical counterparts of the most important and precious documents can be obtained cheaply and rapidly, and without any risk of error in copying, or likelihood of injury to the originals. And not manuscripts only, but maps and plans, and even the finest engravings; in fact anything, whether drawn, written, or printed, which is represented by lines, can be easily and faithfully reproduced. It has also been applied to the representation of natural objects, scenery, &c., but with less success, owing to the great difficulty of obtaining fine gradations of shade.

PROJECTIONS FOR MAPS OF THE WORLD, STARCHARTS, &c.

The want of unity of design and principle which is shown in the construction of our various published maps and charts has long been recognised as a glaring defect in cartography. With the view of remedying this defect, by securing a uniform system for all geographical maps, Sir Henry James, in 1868, designed a projection for maps, on the scale of 10 miles to an inch, of every part of the world, and published an account of the projection, with tables and diagrams for the construction of the maps prepared by Mr. J. O'Farrell, of the Ordnance Survey. For full particulars of this, which is called the "Rectangular Tangential" system of representation, we must refer our readers to the work itself,* merely remarking that it combines the best principles of projection, and the least possible distortion of the form and area of the features as represented on the maps, with the further advantage of enabling us to put together, as a connected map, any number of sheets that can be required for simultaneous examination. In each map, the meridians and parallels intersect sensibly at right angles, and the whole series would as nearly as possible fit together on a model of the globe 66 feet in average diameter. If other nations would combine with us in adopting the same system, one first meridian,† and one uniform scale or set of scales of representation, the geographical maps of all countries would then exactly correspond, and afford every facility for international comparison and use. It is perhaps too much to expect this, for at any rate some time to come; but we may fairly hope that, at least in our own country, the maps of all parts of the world, whether constructed by Government or by private geographers, will ere long be made in conformity to this excellent system.

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* "On the Rectangular Tangential Projection of the Sphere and Spheroid, &c." Ordnance Survey Office, Southampton, 1868.

† Sir H. James says that the meridian of Greenwich, which is very nearly in the centre of the habitable portion of the earth's surface (Falmouth is so exactly), should be taken as the first meridian for all nations.

While on the subject of projections, we must not omit to mention the geometrical projection of two-thirds of the sphere, invented in 1858 by Sir Henry James, who was the first to devise a geometrical projection of more than a hemisphere. In this, the observer is considered to be looking into, not at, the sphere, from a point half a radius distant from it; and the plane of projection is situated between the eye and the centre of the sphere, at a distance of about two-fifths of a radius from the latter, and perpendicular to the line which joins them. This projection is well adapted for comprehending the relative positions of the various parts of the earth's surface, for the representation of isothermal and isobarometrical lines, and lines of magnetic declination, and especially for charts of the stars. By fixing the point of projection in the axis of a great circle whose pole is in 15° E. longitude, and 23° 30′ N. latitude, a map constructed on the above principle represents that portion of the globe which embraces the greatest quantity of land.

SOUTHAMPTON MAP OFFICE.

The head-quarter establishment of the Survey, at Southampton, is well worth a visit from all who have the opportunity; there is always something new to see, some fresh information to be gained. Here, the visitor may examine at leisure the various map-making and other processes of which we have given a brief outline in this pamphlet. He may trace every step in the manufacture of the sheets, from the time when they are received in manuscript from the country divisions till their final issue for circulation to the public, and may learn more in a few hours than we could tell him in double our present space. Between 300 and 400 workmen of various grades, from the skilled engravers, photographers, and computers, down to the boys who stamp and colour the plans, are constantly employed, under the superintendence of the Engineer officers and non-commissioned officers of the department. The large library in the central building is full of objects of interest. The compensation bars with which the principal bases were measured; specimens of the maps and plans on all the survey scales; archæological and geological models, drawings, and specimens from all parts of the kingdom; photographs and photozincographs without end; the volumes of national manuscripts; the models, collections and publications of the surveys of Jerusalem and Sinai; in fact, examples of all the work achieved by the department, are here collected for examination. The photographic building, where the plans are reduced, is a model in its way; so are the map stores, and the store for copper plates. There is also an excellent meteorological observatory; and an astronomical observatory, in which, besides the usual instruments, the visitor may see the Airy's zenith-sector* which was used in finding the latitudes for the English arc of meridian, having been made expressly for this purpose; and the wonderful old three-feet theodolite, made by Ramsden for the Royal Society, which, after having been in almost constant use on the Great Triangulation for nearly seventy years, during which time it was placed on the highest church-towers and loftiest mountains in the kingdom, remains to this day in perfect working order.

No one can go through the department without being struck with its admirable efficiency and organization, as well as with the adroit and ingenious manner in which modern scientific improvements and discoveries, and all possible devices for economizing labour, have been turned to account for the cheap and rapid production of what are probably the best maps in the world. It is in this way, and by their high scientific attainments, that the energetic Director-General and his executive staff have brought the survey to its present state of perfection. So great, indeed, were the advantages gained by the introduction of photography, zincography, and electrotyping, of the various mechanical appliances to which we have here and there referred, and of improved methods of conducting the work, as well as by his own peculiar faculty for organization, that, a few years after his accession to office, Sir Henry James was able to reduce his estimate for the survey to one-half of that of his predecessor. If the work continue to be carried on upon the system and under the superintendence to which it owes so much of its success hitherto, and if Parliament will only sanction a steady and liberal annual grant, the parent survey of the kingdom will be finished in a few years, for less than the cost of a "first-rate" ironclad. And we end our sketch of this remarkable undertaking by reiterating the confident prediction that the national survey, conducted, as at present, on sound and enlightened principles, will amply repay its cost, and prove a wise and beneficial application of public money.

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* Ramsden's zenith-sector, which was also used for these observations, was afterwards burnt in the great fire at the Tower.

H. S. P.

Ordnance Survey Office, Tunbridge,
June, 1873.

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